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P01/7700 0.00-0323906.8

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1. Your reference — PB/P1/03

2. Patent application number *(The Patent Office will fill this part in)* — 0323906.8 — 11 OCT 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — DR. PALITHA BANDARA
SCHOOL OF DESIGN
UNIVERSITY OF LEEDS
LEEDS LS2 9JT

Patents ADP number *(if you know it)* — 8731317001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — Instrument for measuring the tension in a textile yarn using non-contact sensing

5. Name of your agent *(if you have one)* —

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — Harrison Goddard Foote
31 St Saviourgate
York
YO1 8NQ

Patents ADP number *(if you know it)*

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
-		

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — No

Answer YES if:
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
Otherwise answer NO (See note d)

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	/
Description	6
Claim(s)	–
Abstract	–
Drawing(s)	2 + 2

CF

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/~~We~~ request the grant of a patent on the basis of this application.

Signature(s) [signature] Date 10-10-2003

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

Dr. P. Bandara
Tel: 0113 2333786
email: m.p.u.bandara@leeds.ac.uk

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Notes

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Instrument for measuring the tension in a textile yarn using non-contact sensing

Introduction

This invention relates to an instrument for the determination of tension in a textile yarn without physically contacting it. The yarn may be stationary or moving. The instrument is suitable for handheld or for machine mountable use.

Background

The measurement of tension of yarns produced by or supplied to textile machines is important for related quality assurance and process control functions. While the term 'yarn' is used in the following text for convenience, it may represent many types of textile strand such as cords, braidings or cables which are relatively strong, or even rovings or slivers which are weaker, in the context of the instrument identified.

Physically, a yarn may consist of a number of continuous filaments or be spun out of relatively short fibres. As such a yarn may have a twist given to it, and a degree of unevenness of cross section along its length. Spun yarns also have a certain amount of hairiness. Yarns are often dyed to impart them a colour as required by the products that they are converted to. On a textile machine, the yarns move at some speed, ranging from a few millimetres per second to tens of metres per second.

Tension measurement of a yarn is carried out over a suitable span of it, usually between two yarn guides. Contact type tension measuring instruments that employ the well known 3-point measuring principle are most commonly used for this purpose. This type of measurement is simple in that it gives a direct reading of the tension in the yarn. However the measurement suffers from the following drawbacks, the principal one of which is the significant measurement error introduced by the frictional drag on the yarn caused by the measuring tips.

- considerable (5-15%) measurement errors due to friction
- the tension of the strand may be affected by the 'intrusion' caused by the probe tips
- physical contact may abrade or otherwise damage the yarn
- need of mechanical manipulation for threading in of the yarn
- difficulties may be experienced in measuring tension of moving threadlines

Non-contact yarn tension measurement is a very desirable alternative as it will overcome the above problems. This invention describes a specific method of applying an optical sensor to realise a non-contact sensing method, specifically suitable for the detection of the tension of a textile yarn passing over two yarn guides.

The basic measuring principle

A textile yarn passing over two guides is likely to undergo transverse vibrations at a frequency determined by its tension. A textile machine produces a certain amount of vibration in its operation, and these tend to induce natural vibrations in open runs of

the yarn found on it. Furthermore, yarn motion aided by guide friction also tend to induce such vibrations. The frequency of such natural vibration has a clear relationship to the tension in the yarn as indicated later. The basic tension measuring principle based on the natural frequency of vibration has been known for a long time, but problems associated with detecting a textile yarn satisfactorily have had thwarted the realisation of a reliable general purpose non-contact yarn tension measuring instrument based on that principle.

The basic construction of the instrument

The instrument consists of an optical sensing head and associated electronic circuits for the detection of the lateral movement of the yarn due to natural vibrations, and an electronic processing unit for data acquisition, analysis and display of tension readings.

Fig. 1 shows the basic layout of the instrument.

The sensor head employs an optical sensor of the Charge Coupled Device (CCD) type linear array, on the recognition that this type of device can advantageously be harnessed to overcome the sensing problems specific to textile yarns as identified below.

The CCD produces an output signal which is fed to the detection circuit so that after some initial amplification and detection, a signal is developed which corresponds to the transverse position of the vibrating yarn.

The signal processor electronics samples this signal repeatedly at a fixed rate, and carries out a frequency analysis on the acquired data so as to identify the natural frequency of vibration of the yarn. As the distance between the two yarn guides and the mean linear density of the yarn are known, the tension of the yarn can be calculated by using the relation

$$f = \frac{n}{2l}\sqrt{\frac{T}{\rho}}$$

where f = the natural frequency of vibration
l = distance between supports
ρ = linear density of the yarn
T = tension in the yarn,
n = 1 for the fundamental natural frequency

The above equation is well known and has been used in some applications for the determination of tension in a tensioned strand (string, cable, rope etc). Textile yarns have been found to obey this relationship closely enough to permit its use for tension measurement. Occasionally depending on the level of tension, a higher harmonic vibration may be encountered, and care is necessary to avoid an incorrect

determination. Experience has shown that in the majority of measuring situations, it is the fundamental mode of vibration that is involved.

Sensing issues

Trying to apply this method to textile yarns is however confronted with a number of problems. These are

- Most textile yarns are very thin and perhaps too delicate for mounting any sensor directly on it to determine its frequency of vibration.
- The yarns are almost always in a moving state, sometimes at many metres per second, so mounting a sensor on the yarn becomes impracticable.
- The non metallic nature of yarns rules out use of capacitive or magnetic sensing

Optical sensing is found to be the most promising method of using non-contact sensing for measuring yarn transverse vibrations. Application of the method will be much easier if the yarn can be allowed to partly obstruct the light from a lamp falling on a suitable optical sensor i.e. a situation where the yarn is straddled by the lamp and sensor. While this method is usable in some cases, it is advantageous if the lamp and sensor are on the same side of the yarn, as it enables the sensing of a yarn from a fair distance from it, as well as the possibility of handling multiple threadlines.

A disadvantage is that the sensor has to now work with the light reflected from the yarn, which is of a much smaller magnitude compared with the variation of light involved in obscuration.

Optical sensing of yarns has to hence overcome certain problems to the physical nature of yarns. These are

- The slender optical profile of a yarn, requires strong illumination so as to reflect sufficient light to a sensor
- The variation of the amount of reflected light caused by variations of yarn twist, reflectivity, cross section (unevenness) and hairiness
- 100 Hz flicker caused by fluorescent lighting

The problems of sensing are found to be more severe when the yarn is in motion. The method described in the following text provides a non-contact technique suitable for general purpose use, which overcomes the above problems. Specifically it enables the following:

- determination of tension of a textile yarn regardless of whether it is moving or not. When the yarn is stationary, it may be necessary to apply a small jet of air or other appropriate means (e.g. one of the yarn guides may be pizoelectrically actuated) to excite the yarn. This action can advantageously be electronically controlled through the detection circuitry.
- freedom from the effects of reflectivity, evenness or hairiness of a yarn
- immunity to variations of illumination, including ambient lighting
- ability to sense a yarn without straddling it

- suitability for measuring the tension of yarns which are too delicate or otherwise not suitable for application of contact type tension probes.
- The sensing and detection scheme, without the incorporation of data processing elements, provides a non-contact sensor suitable for monitoring of the transverse position of a yarn or other such slender element, applicable in a variety of industrial situations.

Details of the instrument

a) The sensor head

A specific embodiment of the sensor head is shown by the schematic, Fig 2. The yarn under measurement is illuminated by one or more high intensity light emitting diodes (LEDs). In use, the sensor head is placed at the right proximity to the yarn, so that the image of the running threadline is formed on the CCD array by means of a lens based focusing arrangement. As shown later, accurate focusing is useful, but not essential. It is also possible to incorporate an automatic focusing arrangement. Where two or more illuminating LEDs are used, they can be so placed that their beams intersect at the correct position of the yarn with respect to the sensor head. The LEDs could be of two or more colours, so that where the beams cross, the illumination would be of a different colour. Employing two or more indicator lamps, driven from the detection circuitry can be helpful to achieve rapid positioning. This kind of arrangement facilitates positioning the detector head, particularly when it is handheld.

Fig 3 shows the general form of the output from the CCD array. The waveform or 'frame' shown is one complete sequential output available from the linear array . The waveform is characterised by an initial brief drop in voltage level following the output sequence, which corresponds to an internal reset operation of the output sequence. The signal may have a number of small peaks, and when used with a yarn as implied here, there will be a major peak corresponding to the position of the yarn. As the yarn vibrates, its transverse position with respect to the sensor varies, and this is reflected in the varying position of the peak in each frame of waveform.

As this variation is proportional to the movement of the yarn, the yarn vibration can be detected from the CCD output signal. As the detection is based on the position of the peak and not the actual amplitude of the signal, the determination is not affected by fluctuations of illumination level, or the variation of reflected light due to reflectivity, hairiness or evenness variations of yarn, so long as the signal output is sufficiently high to enable effective detection. This was the reason why the CCD linear array was recognised as specifically suitable for the sensing of a textile yarn.

The peak will be tall and sharp when the yarn is well focussed on the CCD as shown by Fig 3 (a). When focusing is less sharp, the waveform will be as shown by Fig. 3 (b). However the position of the centre of the peak still indicates the position of the yarn. This allows some tolerance in the positioning of the sensor head with respect to the yarn, about the position for best focus. In a typical embodiment, the variation of 5 mm on each side of the correct position in front of focusing optics (at a focal length of 7 mm) allowable. The output signal shown by Fig. 3 can be made to repeat at a rate such as 1 kHz. This permits handheld use of the sensor, since in a measurement period of 1 second about 1 k frames can be acquired.

2) Detection circuitry

At the normal tension levels encountered, and range of yarn counts and span lengths encountered, textile yarns are found to vibrate at frequencies normally below 500 Hz. This suggests a minimum speed of 1 kHz for sampling the yarn vibration. The output signal amplitude from the CCD essentially depends on the exposure time, or the time per output cycle. The 1 kHz sampling rate was found acceptable.

Fig. 4 is a block diagram of an embodiment of the electronic circuit used to develop a signal giving the yarn vibration information. The method described below measures the 'distance' from the beginning of a frame to the position where the peak signal occurs by converting the corresponding CCD element number into an 8-bit word. Since exactly where the peak occurs can be known only at the completion of the frame, the output word is latched by the following stages during the last clock pulse of the output cycle of the CCD, which implies a 64 element device in the following description. 65 clock cycles are required to produce one 'frame' of output as shown by Fig.3.

The function of the different block of the detection circuitry shown by Fig. 4 can be explained as follows.

a. A quartz crystal based oscillator and divider circuit A is used to generate the clock signal to drive the CCD. This frequency is required to be about 65 kHz, so that a suitable near 1000 Hz frame output rate can be maintained. It should be noted that the actual frequency used here is not critical. The divider circuit associated with the crystal provides other timing signals required by the following stages.
b. Amplifier stage B raises the output signal amplitude to a level sufficient for further detection, and permits adjustment of its DC level.
c. The peak detector and hold stage C outputs follows peak values in the signal waveform.
d. The comparator D compares the instantaneous signal level with the peak level held in the peak detector. So long as the signal is smaller than its previous peak, the comparator output is 0. Detection of a new peak higher than the previous changes the output to a 1.
e. The binary divider stage is used to generate the necessary outputs to enable generation of frame reset signals required by the CCD as well as the counter (F) and latch (G) circuits.
f. The output of stage D is used to control counter stage F. The counter is stopped by this signal each time a new peak is detected.
g. The counter stage F is zeroed as each new frame of output signal is started. It then counts the clock pulses continuously till the completion of the frame. It is an 8 bit counter so its count can be in the range 0-256.
h. Latch G copies its input, which is the count produced by counter F, so long as it receives an enable signal from the comparator D. It can be seen that after passing the highest peak in the signal, which corresponds to the position of the yarn during the current frame, the latch just stops till the end of that frame.

j. This reset signal causes the reading saved in latch G to be latched by the digital to analog converter H, so that at the end of the frame, the converter output corresponds to the transverse position of the yarn during the corresponding time interval. Instead of being copied into the D to A converter, the output can be copied into an 8 bit latch, which will give the same information digitally to be read directly into a data processor.
k. In the current version of the instrument, the output of the D to A converter is amplified (2.5V full scale) by amplifier stage I , and filtered sufficiently to remove glitches. This output is the analog of the transverse movement of the yarn.

3) Data Acquisition and Analysis

This output signal is sampled precisely at 1000Hz (or other such frequency chosen), by data processor (Laptop PC or DSP) with suitable data acquisition hardware, and processed using an FFT routine to extract the frequency which has the highest signal amplitude, which corresponds to the yarn natural frequency. Certain precautions should be built into prevent the pickup of a wrong frequency, but where repetitive reading is carried out it is relatively easier to ensure correctness of analysis.

The frequency information together with the yarn linear density and the yarn span length are used to calculate the yarn tension. The results can be displaced suitably according to the actual data processing arrangement used.

If a D to A stage is not used and the digital count is supplied direct to a data processor, it will be necessary for oscillator A to run at a precise frequency (65 KHz for a CCD of 64 elements), to provide 1000 Hz sampling rate, and also possibly provide a synchronising pulse. The 65 kHz rate relates to the fact that for the CCD used (Texas Instruments TSL214), each cycle employs 65 clock cycles.

The tension of a yarn normally has a continuous variation, and therefore the data captured over the measuring interval would reflect this variation. It would be possible to take into account the signal amplitudes other than the highest to derive the profile of tension variation over a continuous measuring interval.

Compatibility with contact type tension measuring instruments

The instrument is particularly suitable for measuring the average level of tension in textile yarns for process control purposes. The readings provided by this method were found to compare well with those obtained by conventional methods. In fact the non-contact method is not affected by contact friction and hence give readings closer to their true values. The instrument can be used as a handheld device or is suitable for machine mounted yarn tension monitoring involving single or multiple threadline situations.

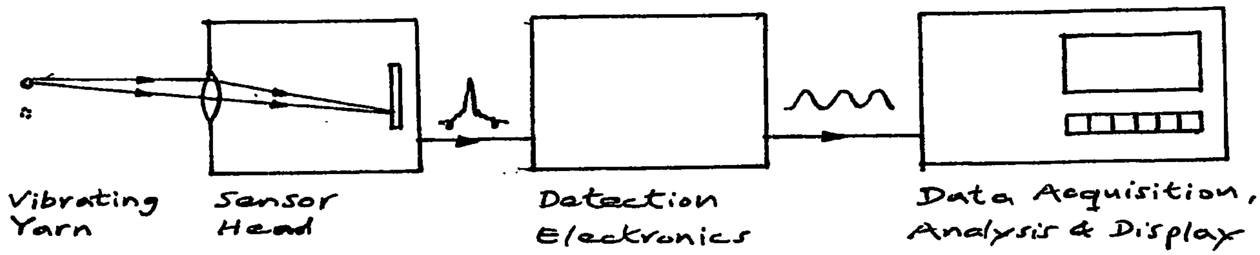

Fig 1

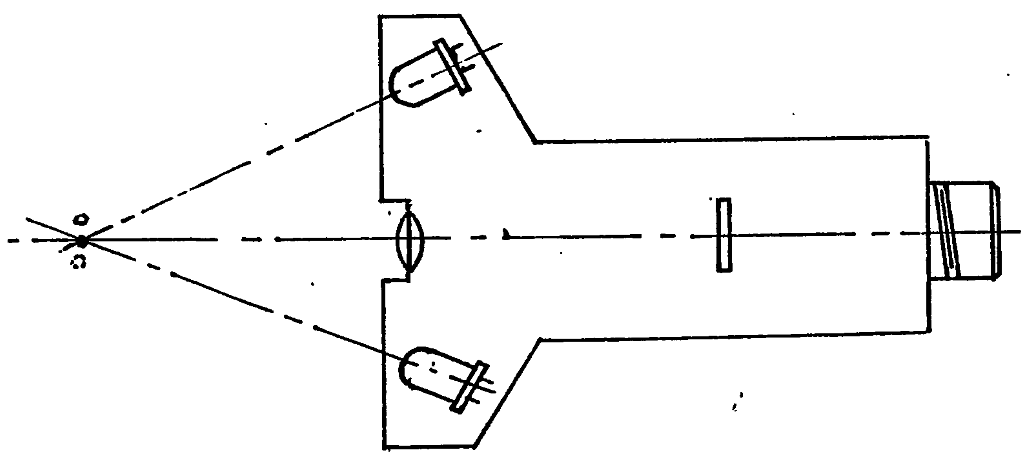

Fig 2

(a)

(b)

Fig 3

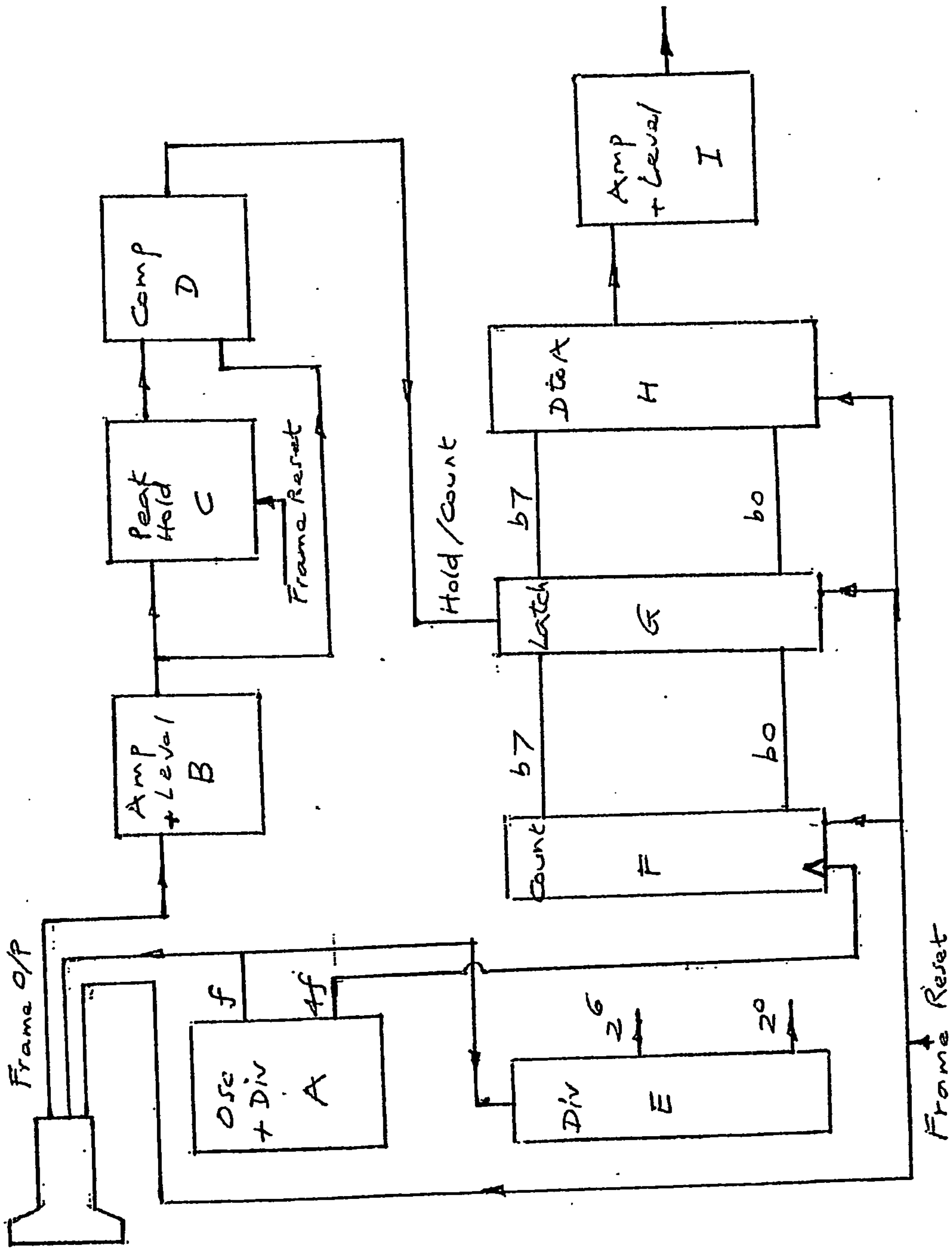
Frame O/P
Osc + Div A
f
4f
Div E
2^6
2^0
Frame Reset
Amp + Level B
Peak Hold C
Frame Reset
Comp D
Hold/Count
Count F
b7
b0
Latch G
b7
b0
D to A H
Amp + Level I

Fig 4